results.

## 2. The Model

The major actors in our model of workplace safety and health are OSHA and private companies. OSHA sets standards, inspects plants, and issues citations and penalties when violations of the standards are detected. Each company is assumed to choose a level of compliance with the standards. The compliance level, in turn, has implications for the workplace safety and health quality level. In this paper we focus on company responses to agency enforcement (and the implications of the violation level for workplace "quality".)

Following the tradition in the plant-level analysis in the OSHA literature, we employ a specific-deterrence framework. The longitudinal structure of our data allows us to provide a far richer picture of longitudinal patterns of inspection and compliance through the first 12 years of the agency's history than possible in previous studies. To measure agency enforcement, we employ dummy variables indicating the sequence number of the inspection from the first through the fifth inspection [SEQNUMj, j=1,...,5] and a continuous variable denoting each additional inspection after the fifth [SEQNUMC].[8] At any given point in time, the number of previous inspections

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8. The variable equals total inspections - 5, for those plants with more than five inspections, and 0 otherwise.

signals the intensity of (past) enforcement.[9] As noted earlier, the initial inspections may disseminate information about OSHA requirements and may provide a "management shock" to action. These functions are potentially crucial. Though the specific deterrence framework explicitly models the response of firms to past inspections, we implicitly assume that at least part of the response is motivated by anticipation of penalties in future enforcement actions. Though penalties for initial violations tend to be very low, the penalty schedules for repeat and willful violations cited in subsequent inspections are substantially higher.

We assume each company chooses a level of compliance with workplace health and safety standards, based on expected benefits and costs of the expenditures. The costs of compliance include the expenditures on machinery, protective clothing and equipment, and the foregone revenues associated with a slower workpace or alternative operating procedures necessary to comply with the standards. The benefits of expenditures to control hazards include avoidance of expected non-compliance penalties, as well as satisfaction of the firm's preferences for law-abiding behavior. We do not have direct measures of the benefits and costs; rather, we assume that they vary with the employment size

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9. We implicitly control for the elapsed time between inspections by including a variable measuring total number of inspections a plant receives during the panel period (NINSP). The role of this variable will be discussed further below.

(ESTSIZE) and industry (SIC) of the plants.

The OSHA enforcement data indicate the number of violations cited and the penalties levied in inspections. Because the citation data form the basis for our violation measures, we consider several factors which may affect the consistency of the relationship across inspections or through time between "true" violations and our measures of violations. The number of citations provides a measure of violations of all OSHA standards and the occurrence of worker exposure measurements provides an indicator of violations of OSHA permissible exposure limits for hazardous substances.[10]

First, different Administrations may vary in the rate at which enforcement officers choose to cite various types of violations. For example, the agency was widely criticized in its initial years for extensively citing trivial standards. OSHA substantially reoriented its policy in 1977, emphasizing detection of violations of more serious standards.

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10. See our detailed study of the exposure data [5], for further discussion of sampling and reporting issues associated with the exposure data. An in-depth study of records in two OSHA offices indicated that compliance samples were taken in 64% and 76% of all health inspections but samples were reported in approximately half of those inspections. However, in our study the lack of reporting appeared to be random: Contrary to our prediction, the distribution of severity levels for all samples taken (as indicated in area office files) was approximately the same as the distribution of severity levels for all samples reported in the MIS by area offices. We are unable to make any definitive inferences about the workplaces in which no samples were taken.

We control for variations in citation policy across Administrations with dummy variables for each year.[11]

Second, the origin of each inspection (complaint, follow-up, general schedule, accident) affects how much of an establishment is inspected, and therefore affects the likelihood that violations will be detected. General schedule inspections involve the broadest coverage of the workplace; complaint and follow-up inspections are generally narrowly focused on the subjects of the complaint or of past violations, respectively. To control for these variations in the relationship between "true" violations and citations, we will include dummy variables for inspection origin in the equation.

Third, the relationship between measured violations (citations) and "true" violations is affected both by the skill of the inspectors in detecting violations and by the skill of plant managers in practicing subterfuge. It is likely that both have increased through time. The net effect is indeterminable, but we do not expect that variations in relative detection/subterfuge skills across time periods will produce serious bias. Finally, the relationship is affected by the

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11. However, the penalty policy associated with repeat and willful violations (which represents an important source of the deterrent threat associated with repeat inspections) changes across Administrations, so these variables are capturing a variety of effects. As a result, the coefficients must be interpreted with care (since they incorporate both agency citation behavior and deterrent effects on violations by firms.)

relative shares of detectable and non-detectable violations. Not all violations are detectable. Non-detectable violations include short-term stochastic events that are unlikely to be detected because inspections are relatively infrequent. If non-detectable violations are reduced by OSHA inspections less effectively than detectable violations, the observed decrease in detectable violations will overstate the decrease in "true" violations through time.

Note we only observe the violation level when an enforcement officer inspects an establishment. Forty percent of the plants are inspected only once, yet 2% [N=2667] have experienced 10 or more recorded inspections. This process of selecting observations into the sample potentially leads to serious sample selection bias. If OSHA is effective in targeting high violation plants for inspection, plants repeatedly selected for inspection are likely to be different from infrequently or never inspected plants. Enforcement officials may use information in their targeting process that is not available to the researcher, such as the local reputation of the plant. If plants that are inspected different numbers of times are consistently different from one another in ways we [the researchers] cannot measure, then estimates of the deterrent effect of inspections. Because we do not model directly the non-random selection process, they may be biased estimates of the effect of inspections in the universe of plants. In essence the problem occurs because we do not observe each plant in the sample the same number of times.

In our analysis, we will allow the estimates of company responsiveness to inspections to vary across the sub-samples [defined by the total number of inspections.] As discussed above, our estimates of the deterrent effects will be conditional upon the sample. If the deterrent effects are consistent across subsamples, however, we will have greater justification for making inferences beyond the sample.

We control for the selection effect by incorporating a variable measuring the total number of times a plant is inspected during the period, [NINSP], and by interacting the inspection [SEQNUM] dummy variables with NINSP. As with SEQNUM, for NINSP we employ dummy variables equal to 1 through 5, and then a continuous variable for additional inspections. For the first five inspections, we include SEQNUM and NINSP interactions. For inspections after the fifth, we assume the inspection-related deterrent effects are the same across the NINSP sub-samples. We also run a version of the regressions without the interaction terms.

All the other explanatory variables are also incorporated as dummy variables.

The estimating equation then becomes:

$$(1)\ V_{ij} = a_0 + \sum_k \sum_q a_{1,k} SEQNUM_{ik} * NINSP_{i,q} + a_2 SEQNUMC_{ij} + \sum_m a_{3,m} INORIGIN_{ij,m} + \sum_n a_{4,n} INYR_{ij,n} + \sum_o a_{4,o} SIC_{j,o} + \sum_p a_{5,p} ESTSIZE_{j,p} + \sum_q a_{6,q} NINSP_{i,q} + a_7 NINSPC_i + e_{ij}$$

where the subscript i refers to plant i, subscript j refers to inspection sequence number j, and k, m, n, o, p, and q are indices of the dummy variable sequences. We predict that as the number of inspections of a plant increases, the numbers of citations in subsequent inspections declines. If unmeasured plant-level effects result in heteroskedastic errors, OLS estimators for equation (1) will be consistent but not efficient. Due to the extremely large sample size, however, inefficiency of the estimators is not a major issue.

We will estimate equation 1 both for the number of violations cited and, in the health analysis, for the number of worker overexposures.

## 3. Data

The source of data for the analysis is OSHA's enforcement Management Information System, used by the agency to track agency enforcement and company compliance performance. The version of the MIS data obtained for this study includes the 299,295 federal inspections performed in manufacturing establishments between 1972 and the middle of 1983.[12] The MIS provides information about OSHA's enforcement actions identifying which standards are

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12. Not included in the data are those few inspections done in 1971 and 1972 before the MIS was operational and inspections performed in "state plan" states, in which state authorities have taken over responsibility for enforcement and OSHA only performs occasional inspections.

cited and what penalties are levied. It also identifies the inspection origin (complaint, general schedule, accident, or followup), category (safety and health), and date of occurrence. Information is also provided about establishment characteristics, including the number of employees and industry, as well as individual plant identifiers.

In order to create longitudinal records of plant inspection histories, Gray [1986] matched all inspections of individual establishments using establishment-level identifiers.[13] The weights given to agreement and disagreement on the data items used for matching determine the relative shares of Type I and Type II errors in linkage. Because of the variation in coding of establishment data over time (including errors in data entry), there are almost certainly cases in which inspections of the same establishment are not identified as such. It is also possible (though less likely given the structure of the weights) that inspections of different establishments are mis-identified as repeat inspections of a single establishment.

Table A1 describes the means and standard deviations of the first analysis sample: all health and safety inspections. The

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13. This project used the Fellegi-Sunter technique of record matching, based on the likelihood of agreement on the various fields. For example, exact agreement on establishment name between two inspections makes it very likely that they refer to the same establishment, while agreement on industry (without agreement on several other fields) does not lead to the conclusion that they refer to the same establishment.

matching procedure identified 115,236 plants in the sample. Approximately 42% of the plants were inspected only once. The conditional probabilities of subsequent inspections were approximately 60%, (almost) independent of the current sequence number. For example, conditional upon having been inspected once, the probability of a second inspection was 57%; conditional upon having been inspected eight times, the probability of a ninth inspection was 67%.

The inspections were fairly evenly distributed through time. Approximately 1 in 5 were health inspections. General schedule targeting procedures generated approximately half of the inspections. Complaints or follow-ups to previous inspections motivated approximately one-quarter of the inspections. Accident investigations comprised a minimal 2% of inspections. Inspectors wrote citations in 58% of the inspections, averaging 4 citations across all inspections and 7 citations in inspections with citations.

For the analysis focusing solely on OSHA health performance, we employ two additional datasets, each a subset of the previous one. The second dataset includes all health inspections [N = 63,383]. The third contains only the health inspections with samples of worker exposures to hazardous substances. The descriptive statistics for the health datasets appear in Table A3. Comparing Tables A1 and A3 (col. I), we see that relative to all [health and safety] inspections, health inspections are

slightly less likely to have citations (49% relative to 58%) and on average have fewer citations (2.5 relative to 4.2). A greater percentage of health inspections than of safety inspections occur among more intensively inspected plants and larger plants.

Table A3, col. II, indicates that in plants with worker exposure measures, on average, 1.5 exposure samples (27% of the total) violated the standards. Not surprisingly, relative to the average health inspection, inspections with samples have more citations on average, but the difference (3.4 relative to 2.4) is not significant. Otherwise, the two samples look very similar.

## 4. Empirical Results

The major issue considered in this paper is: Do OSHA's enforcement efforts deter violations of OSHA safety and health standards? In this paper we test the specific-deterrence model of OSHA impact, which posits that repeated inspections of an establishment provide incentives to reduce violations of OSHA standards, and thereby increase workplace safety and health. In the first section below we report on the determinants of health and safety citations in all health and safety inspections. In the second section below, we estimate the model for health inspections only.

We will examine alternative specifications of control variables to determine how sensitive the results are to

specification error. The analysis will proceed through increasingly more complete sets of controls, identifying how much additional information the added controls provide as well as the effect they have on the estimated relationships between repeat inspections and compliance.

## 4.1 Longitudinal Citation Patterns for all Health and Safety Inspections

Table 1 reports the simplest possible longitudinal analysis, identifying how the average number of citations varies with inspection sequence number. The results suggest that the initial inspection of an establishment may reduce subsequent violation levels, but that the following inspections have little effect on compliance. These results are misleading, however, because the agency decision to perform repeated inspections of a plant is highly correlated with poor compliance performance.

Table 2 displays the pattern of violation rates in sequential inspections (SEQNUM), controlling for the total number of plant inspections (NINSP) during the 1972-83 panel period. The pattern, which is remarkably consistent, confirms that the plants OSHA chooses to inspect repeatedly tend to have higher violation rates. To a great extent, the greater the total number of inspections experienced by a plant (NINSP), the greater the number of citations (NUMCITE) for a given inspection sequence number (SEQNUM). The differentiation appears to be weaker among classes with five or more inspections, but it is important to

Table 1. Effect of sequence number on citation variables. Sample = All safety and health inspections (N=299,295).

| SEQNUM | NUMCITE |
|---|---|
| 1 | 6.3 |
| 2 | 2.8 |
| 3 | 3.1 |
| 4 | 2.7 |
| 5 | 2.8 |
| 6 | 2.6 |
| 7 | 2.6 |
| 8 | 2.6 |
| 9 | 2.5 |
| 10-14 | 2.6 |
| 15-19 | 2.4 |
| 20+ | 2.4 |